Identification of Fission Neutrons from the ^{252}Cf Calibration Source at SNO

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The Sudbury Neutrino Observatory is sensitive all active flavors of neutrinos ($\nu_x, x = e, \mu, \tau$) through the neutral-current reaction ($\nu_x + d \rightarrow n + p + \nu_x$). In the pure D_2O phase of the experiment, the neutron signature is a 6.25-MeV γ ray from the radiative capture by d. At the Sudbury Neutrino Observatory, a ^{252}Cf source is used to calibrate the neutron capture efficiency and the energy response to this 6.25-MeV γ ray.

The difficulty in extracting the $d(n,\gamma)$ photopeak using this source comes mainly from the contamination due to p(n,γ) captures, and fission γ's from the calibration source itself. If the photopeak can be reliably extracted, one can provide an independent cross check of the ^{16}N energy calibration, which is the default energy calibration source in SNO.

We have developed a technique to separate the $d(n,\gamma)$ events from the other undesirable background events. A brief description is provided in the following. In a ^{252}Cf fission event, an average of 3.7 neutrons, along with other fission fragments are emitted. Signals from the fission γ's are prompt, whereas neutron captures are delayed because of neutron thermalization. Let us consider two consecutive events observed in the detector: $\mathcal{E}_\circ$ and $\mathcal{E}_1$. $\mathcal{E}_1$ is the event immediately before $\mathcal{E}_\circ$. $\mathcal{E}_\circ$ is more likely to be a $d(n,\gamma)$ event if $\mathcal{E}_1$ has a large number of photomultiplier tube hits (N_{hits}) because of the neutron multiplicity. However, $\mathcal{E}_\circ$ can be a $p(n,\gamma)$ capture in D_2O, the source's arylic capsule, or the acrylic vessel. The first component has a small contribution. By placing a fiducial volume cut around the source for $\mathcal{E}_\circ$ one can reduce the effect of the last two components because the range of neutron random walk is much longer than the γ ray attenuation length.

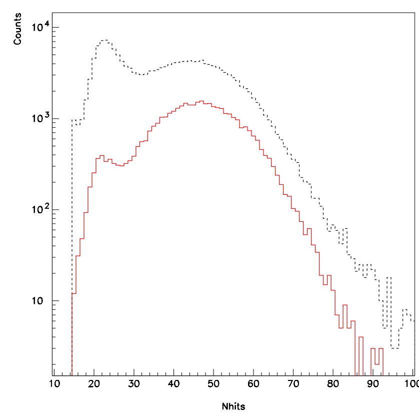

Figure 1: N_{hits} spectrum for ^{252}Cf calibration. *Dashed*: raw N_{hits} spectrum for the ^{252}Cf source at the center of the detector. *Solid*: N_{hits} spectrum extracted using the coincidence technique.

The ability to reduce the background contamination in the $d(n,\gamma)$ photopeak using this neutron-neutron coincidence technique is demonstrated in Figure 1. In this figure, the raw N_{hits} spectrum for the source located at the center of the detector is shown. The $d(n,\gamma)$ photopeak obtained from this neutron-neutron coincidence is also shown in the figure. It is clear that the low energy background contamination in this latter spectrum is much smaller. This coincidence technique is particularly useful when the ^{252}Cf source is closer to the acrylic vessel of the SNO detector. As the hydrogen in the acrylic vessel is more effective in capturing the neutrons, the $d(n,\gamma)$ peak is hidden under the tail of the low energy background in the raw N_{hits} spectrum. However, a clean $d(n,\gamma)$ peak can still be extracted using this coincidence technique